HOW DANGEROUS IS RF RADIATION? — Part One

From time to time, we receive requests from amateurs and even people in the commercial field, to give a view on the hazards of RF radiation. Of particular interest to radio amateurs are the VHF and UHF hand held transceivers. Newer models coming onto the market have the capacity to run up to ten watts of RF out.

The WIA is most interested in any reports in respect of RF radiation hazards. Microwave radiation is also a most important discussion area.

To give a fair view of what results have been ascertained in tests overseas, we have collated several articles from QST, and Radio Communication to help educate the Australian radio amateur in the possible hazards in the operation of VHF and above.

The articles are self explanatory, and the WIA or 'Amateur Radio' magazine assumes no responsibility for any of the statements made. The articles will be published as a series for the next three issues, and we would appreciate your thoughts on the matter when all of the articles have been published.

Here are the first of three articles in the series.

VK3UV

RF HEATING IN THE AMATEUR BANDS

By A. Peter Ruderman, PhD, *VE1PZ
Reproduced from QST June 1978

An amateur licence is a licence to transmit RF energy. When you key your transmitter you generate electromagnetic and electrostatic fields around your antenna; when you receive you are tapping the far weaker fields that started at the output of someone else's transmitter. We are immersed all the time in the very weak fields of all the transmitters in operation anywhere in the community: those of other amateurs, commercial stations, CBers, airport control towers, paging systems, microwave ovens and even 60 Hz power transmission lines.

RF radiation is often referred to as non-ionising radiation in order to distinguish it from the ionising radiation that is associated with X-ray equipment and nuclear power plants. There are important differences: Ionising radiation, for example, can have a cumulative effect. (This is why atomic plant employees and uranium miners have a lifetime total safe dose to worry about.)

Non-ionising radiation can hurt people when it causes a build-up of heat by agitating the molecules in some part of the body. An increase of 2 degrees C in the temperature of the testicles can cause temporary sterility. An increase of 10 degrees C in the temperature of the eye can cause cataracts to form. This damage is permanent. Greater increases in temperature can be fatal by literally cooking your insides.

Normally, the effect of RF exposure is not cumulative unless tissue damage occurs, since whatever heats up can cool down. The damage caused by RF radiation depends on the amount of power, distance of the individual from the power source, amount of shielding, and above all the frequency. The frequency determines how much heat will be generated in the body from a given amount of RF power. It takes only some simple commonsense precautions to protect amateurs from RF damage in most cases.

A LOOK AT THE AMATEUR BANDS

From 1.8-30 MHz most of the radiation passes right through you without any after effects. Only a small amount is converted to heat. If you consider that a 1 degree C rise in temperature is tolerable (i.e., like the low fever of a mild cold), you might have to spend an hour or more just three feet away from the feed point of an antenna radiating 500 watts of power at 8 MHz to achieve this effect.

At 144 MHz enough energy is absorbed to cause more rapid heating, and a body close to the energy source at moderate power over a prolonged period can suffer harm.

At 420 MHz about half of the RF energy is converted to heat in the body. This is probably a real danger point.

From 1000-3000 MHz the RF energy is almost completely absorbed in the body. Microwave ovens fall in this range.

At 10 000 MHz we are back to half the energy being absorbed. Still higher frequencies tend to be reflected instead of passing through, as at communication frequencies. The wavelength is such that the energy can just hit the nerve endings in the skin and provide nature's warning signal of feeling the heat.

SAFETY STANDARDS

If you are operating in the 10 metre band with 1 kW of radiated power, and the operating position is 10 metres from the antenna, the power density on the operator would be about 0.8 mW/cm^2. This looks safe enough, and in fact the radiation pattern from the vertical, dipole or beam, would be such that an amateur 10 metres below the feed point would be receiving less than the theoretical radiation.

Unless there were serious leaks, poor shielding, lots of RF in the shack from radiating feed lines, unbypassed leads, etc., there does not seem to be much of a problem.

2 METRES AND UP

At 144 MHz and higher, the picture is quite different. First of all, more of the RF energy is converted to heat in the body. Second, although power is generally lower, a mobile antenna on the car roof is very close to the operator. And a handie-talkie with a built-in microphone brings the operator within a couple of inches of the antenna.

If a mobile operator were transmitting with 10 watts of radiated power, and the antenna was on the left (right in Australia -Ed.) front fender, less than one metre from the driver's seat, you could easily get a power density of 10 mW/cm^2, which might be hazardous in the case of long uninterrupted transmissions. With a handie-talkie, a built-in microphone, and only one watt of radiated power, the density would be three or four times as great.

HOW DANGEROUS IS RF RADIATION?

Reproduced from Technical Correspondence QST Sept. 1978

Workers at Motorola have recently conducted experiments of great interest to most amateurs. Their results have been published in several IEEE publications.

The experimenters constructed a simulated human head and torso and exposed it to the radiated fields from 150 and 450 MHz 6 watt, handheld transceivers. Both radios were equipped with helical or "rubber duck" antennas. In addition, tests were performed with a 1/4 wavelength antenna installed on the 450 MHz unit. A thermal probe was used to measure temperature rise due to exposure. These experiments were performed because of concern that the newer, high-power units might pose a health hazard. Previous measurements of the field strength surrounding these radios had indicated that an incident field intensity exceeding 10 mW/cm^2 might exist. This is a safety standard for human exposure to RF energy at higher frequencies.

Because the field would be concentrated by a probe causing nontypical localised heating, the probe was removed while the transmitter was operating. The "dummy" was exposed from 15 to 60 seconds. After power was removed, the probe was again inserted and the temperature change determined. Steps were taken to prevent thermal transients caused by insertion and removal of the probe. It would have been possible for heating to occur in small areas not being monitored by a probe. To look for "hot spots", an IR (infrared) scanner was used to take thermograms of the dummy.

Assuming the transceiver was positioned as it would be during normal operation, no significant heating effects were noticed on either band. Even at 450 MHz, the temperature rise was slight. At a shallow probe depth (0.2 inch or 5 mm), the greatest temperature rise was less than 1°C. At deeper probe penetrations the temperature rise was less. Attempting to determine possible hazards from a measurement of radiated field intensity may cause misleading results. The low total energy and high field impedance which exist when such radios are brought in close proximity to the body will result in lower energy transfer than field-strength measurements alone would seem to infer. For example, at a point two inches (50 mm) from the helical antenna of the 150 MHz transmitter (Fig. 1), a Narda field probe measured a maximum field intensity of 168 mW/cm^2. This value greatly exceeds the 10 mW/cm^2 exposure standard. Measurements based on the penetrating effects at the same point indicate a maximum power flow density in tissue of 2.8 mW/cm^2. On 450 MHz, with the same spacing from the 1/4 wavelength *whip* antenna (Fig. 3), a maximum radiated intensity of 16 mW/cm^2 was found. Power flow density was only 2.5 mW/cm^2. The radiation meter indicates a hazardous condition, while actual measurement of the effects shows this is not the case. Power *absorption* in all cases was less than 1 mW/cm^2.

IR thermograms did not detect any unusual hot spots. A health hazard exists when the tip of the antenna is close to the eye (within 0.2 inch or 5 mm) and the transmitter is operated. In this case, and RF burn will result on the cornea. The thick plastic cap on the tip of the antenna makes this unlikely to occur. When the radios are held in the normal position for use, no eye hazard exists.

While these tests were performed at 150 and 450 MHz, I think it is safe to assume we need not fear our portable 220 MHz rigs either. These tests point out the fallacy of using radiated field intensity as a criterion of safety. Some consumer publications have begun to measure the field strength radiated from CB radios. Consumers have been warned not to stand close to the mobile whip while a 5 watt CB transmitter is operating, due to the high field strength! These papers have shown that radiated power may greatly exceed that which is absorbed and converted into heat. Amateurs should continue to exercise prudence when using UHF and microwave equipment, of course. It does seem that our portable transceivers pose no threat to our health.

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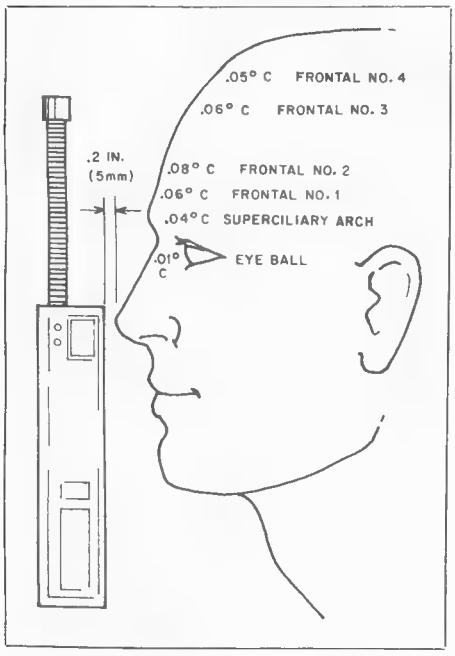

Fig. 1. This drawing shows the position of the 6 watt 150 MHz radio in relation to the head of the dummy. In this configuration, with the transmitter operated for 60 seconds, the temperature increases noted were observed.

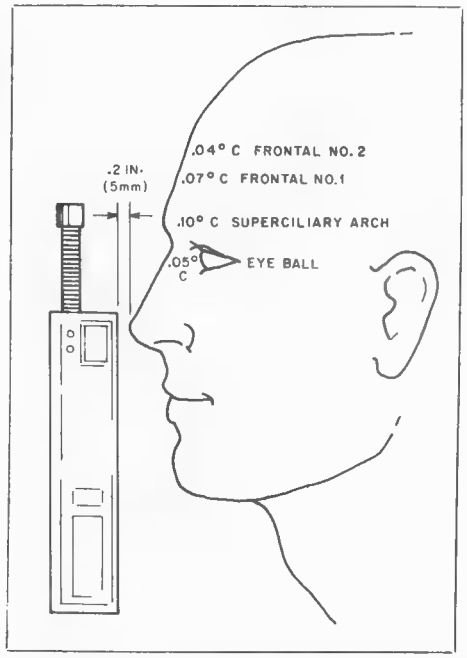

Fig. 2. Position and thermal effects of a 6 watt, 450 MHz radio equipped with a helical or "rubber duck" antenna. A "hot spot" exists near the tip of this antenna. The eyeball is shadowed in its recess and receives very little exposure.

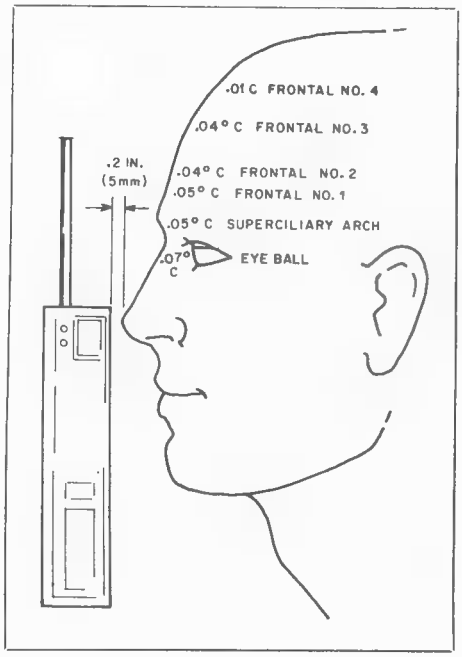

Fig. 3. The same 450 MHz rig, this time with a 1/4 wavelength whip installed. Power density in the eye is greater, but still very low.

ANOTHER VIEW

The article, "RF Heating in the Amateur Bands", which appeared in *QST* for June, 1978, includes some statements which, in light of extensive experiments performed in our research laboratories, are not correct. Although Dr Ruderman properly warns amateurs to use caution to avoid unneccessary exposures, the power-density levels he quotes are too high to be realistic. At a distance of 10 metres from a half-wavelength 10 metre dipole connected to a one kilowatt output source, the power density in the horizontal direction is about 0.08 mW/cm^2, not 0.8 mW/cm^2 as stated by the author. This last value would be found at a distance of 10 metres in the bore sight direction of a 10 dB-gain beam antenna.

Turning to the VHF bands, Dr Ruderman states that a mobile installation transmitting 10 watts effective radiated power (ERP) from an antenna mounted on the left fender, less than one metre from the driver (how much less isn't specified), could expose him to a power density of 10 mW/cm^2. This value is not corroborated by experimentation. Some research departments at Motorola Inc., have conducted careful measurements of power density inside the cabins of cars equipped with mobile transmitters. The Narda model 8310 radiation monitor, calibrated for VHF operation, was used. In the situation described by Dr Ruderman, at a distance of 1.1 m between driver and antenna, the maximum power density measured was 0.05 mW/cm^2, substantially lower (23 dB) than the 10 mW/cm^2 level quoted by Ruderman. The 0.05 mW/cm^2 level is slightly less than the power density one would find in free space (in the direction of maximum gain) at about one metre from a VHF dipole connected to a 10 watt output source.

In the matter of portable transmitters, Dr Ruderman states that 30-40 mW/cm^2 power densities exist in the immediate vicinity of a 144 MHz antenna connected to a 1 watt-output transmitter. These values are not supported by experimental evidence either. First of all, it is difficult to define, let alone measure, power density so close to an RF source. At a point near the radiator, different parts of an antenna contribute fields propagating in completely different directions, precluding any obvious definition of power flow. In these conditions, one can measure only energy density (mJ/cm^3), by separately evaluating the E and H fields with appropriate instrumentation. In the near field, however, the electromagnetic energy density does not have a simple relationship to power flow. Unlike the far-field case, part of the energy is stationary (static type) and part is propagated. To avoid these difficulties, we measured power deposited in simulated humans, by operating 6 watt-output 150 MHz portable radios equipped with helical antennas. Helicals were selected because they caused much higher energy density readings in field probes than did quarter-wavelength telescopic antennas. The results of these measurements were presented in a recent paper.[4] The experiments have shown that, at VHF, electromagnetic energy in the immediate proximity of a portable radio antenna does not penetrate into muscle or brain tissue of the human body. There is energy deposition only in the very surface fatty layers. In addition, it was found that if a user operates a 1 watt portable radio with the case 0.2 inch (5 mm) from his mouth, the maximum absorbed power density (which can be measured from heating effects) is less than 0.2 mW/cm^2. This value is much lower than the deposition levels (8-10 mW/cm^2), due to an incident power level of 30-40 mW/cm^2 which, Dr Ruderman states, exist near a portable transceiver.

I would like to reassure radio amateurs of the absence of any detected thermal radiation hazard from commercially available mobile and portable radio transmitters, if such equipment is properly installed and operated in accordance with simple common sense.

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HOW DANGEROUS IS RF RADIATION? — Part Two

Here is the second in our series of articles on this most important subject. It is reproduced from Radio Communication February 1982 and is printed in its entirety. Next month we will publish the final item in this series covering Microwave RF hazards.

RF HAZARDS AND THE RADIO AMATEUR

by Roger P Blackwell, BSc, G8IZV*, and Ian F White, MA, PhD, G3SEK*
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The biological effects of RF radiation and their practical implications have received a great deal of attention in recent years. Papers on these subjects in professional and scientific journals abound. Unfortunately the echoes of these papers in the amateur radio press have often been ill-informed and in some cases sensationalised. The average radio amateur is left wondering whether RF hazards are truly a cause for concern and, if so, what to do about them.

The authors are radio amateurs who are professionally involved in radiological protection, one being a biologist and the other an environmental scientist. In this article they examine the potential hazards of amateur radio from the viewpoints of radiation biology, RF engineering and commonsense.

Normal good RF engineering practice automatically tends to control potential hazards to the station operator. At fixed stations the normal use of high antennas leads to very low environmental RF power densities in accessible places. Even in the less common cases where areas of relatively high RF power density are potentially accessible, the operator can still control the hazard by preventing access. The authors see no reason for treating RF hazards any differently from other hazards of amateur radio that are better-known, accepted and controlled.

EFFECTS OF RF RADIATION

The quantum energy of RF radiation, which determines what manner of interaction with matter takes place, is very low; orders of magnitude smaller than that required to cause ionisation of atoms or molecules. RF radiation is thus totally different in properties from the ionizing radiations such as gamma and X-rays. The most important effect of RF radiation on biological materials is the induction of rotation of electrically-polarised molecules, such as water. This rotational energy manifests itself as heat. This principle is employed in medical diathermy and the microwave oven.

A great deal of research effort is currently directed towards understanding the biological effects of RF. While the authors would not wish to discourage anyone from taking an interest in this work, they must emphasise that the interpretation of the experimental results is difficult for the layman, and that it is all too easy to jump to the wrong conclusions. The view of the overwhelming majority of Western scientists working on this topic is that heating is the *only* biologically significant effect of RF. There are often reports, mostly emanating from Eastern Europe, of "non-thermal" effects occurring at extremely low power densities. Such reports must be regarded with suspicion, for they fail the basic test of scientific credibility: when independent workers have repeated the experiments the claimed results have not been observed. More credible effects have indeed been observed at RF power densities which, while not extremely low, seem low enough to suggest "non-thermal" origins; but closer examination has shown that they too can be explained by heating, and that what has been detected is the body's reaction to compensate for a very small thermal change induced by the RF field. Although such effects are of scientific interest, they have not been shown to be hazardous, bearing in mind that a "hazard" is a risk of *harm*.

Heating of a part of the body can be considered a hazard if the heat cannot be removed by the body's normal temperature-regulating mechanisms quickly enough to prevent a temperature rise sufficient to damage tissue. Perhaps the most critical organ in this respect is the lens of the eye, because it is near the surface of the body, has no blood supply to remove heat, and has no capacity for repairing damage. Hence the oft-repeated warning about looking down waveguide. There is no evidence whatsoever that RF radiation produces long-term damage of the kind associated with ionising radiations, i.e. cancer or genetic damage.

RF EXPOSURE LIMITS

The Home Office and the Medical Research Council recommend that the maximum for continuous exposure is a power density of 10 mW/cm^2; this limit may also soon appear in the form of a European Community (CEC) Directive. The figure of 10 mW/cm^2 was arrived at over 20 years ago[1] and remains essentially valid today, despite close examination in recent years. Very similar limits are used in the USA and some other countries. Eastern Europe and

Russia have somewhat tighter standards — for example, 10 μW/cm^2 — but there is no valid reason for these from the Western viewpoint.[2]

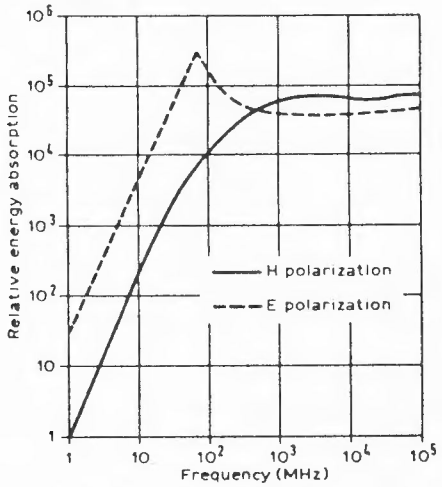

Fig. 1. Relative energy absorption versus frequency for E and H field orientations of an "average man".

Recent work has substantially confirmed the validity of the UK limit over the majority of the RF spectrum.[2] The absorption of energy by a given object depends on several variables, such as the frequency of the radiation, size of the object and the materials of which it is made. For frequencies above 500 MHz the amount of energy absorbed by, for example, an "average man" is relatively independent of frequency. At about 65-70 MHz man is more or less resonant, because his height is approximately half a wavelength; absorption of RF energy, if the subject is oriented parallel with the E-field, is therefore at a maximum and may be possibly 10 times that at 500 MHz. Absorption then falls off rapidly with decreasing frequency, at 10 MHz being less than 10 per cent of that at 500 MHz (Fig. 1). There would therefore appear to be much less of a problem with HF exposures. The 10 mW/cm^2 limit remains equally valid at all frequencies, although the "built-in" safety margins are less around the frequencies at which man is resonant.

DETERMINING RF POWER DENSITY

It is very difficult to predict RF power densities in real-life situations, and none too easy to measure them. The reason for these difficulties is that power densities are likely to be highest close to the source, which is where the electric (E) and magnetic (H) components of the field are not at right-angles as they would be in the "far-field". The difficulty in measuring RF power density when the E-field and the H-field are not at right-angles is rather like that in measuring power in a reactive AC circuit, where the E and I vectors are not in phase. Just as one cannot determine power in the AC circuit by measuring E and/or I separately, one cannot determine RF power density in the near-field region by measuring the E-field and/or the H-field separately.

Very sensitive measurements can be made of the E-field (or less commonly of the H-field) but their interpretation is ambiguous. If one assumes that the two components are at right-angles the power density is simply calculated from the equation

$$W = E^2/Z \qquad W/m^2$$

where E is the E-field in V/m and Z is the "impedance of free space" (377Ω). Although this represents the maximum possible value of W, and may be a considerable overestimate in the near-field region, "derived standards" of the maximum permissible E-field for particular circumstances can be calculated on this conservative basis.

A less ambiguous measurement of RF power density is based on direct detection of the heating effect, but instruments employing this principle are not very sensitive owing to the difficulty of measuring the very small temperature rises involved.

Even under laboratory conditions, accurate measurements of RF power density call for specialised instruments and great care. It is not possible for amateurs (or indeed professionals) to measure near-field RF power density with normal communications test equipment.

However, commonsense suggests that situations in which RF power density *may* be high are best avoided as a matter of principle, even if they may not prove unduly hazardous in practice. Generally speaking, the larger the quantity of RF energy and the smaller the area in which it is confined, the higher the RF power density. Fortunately most of the undesirable situations represent bad engineering practice for other reasons, and some of the authors' strictures are as much against the bad practice as against the RF hazards that might result.

SITUATIONS TO AVOID

1. RF exposures leading to an actual sensation of heating are far in excess of 10 mW/cm^2, and are definitely to be avoided!

2. Looking down a waveguide

The classic example in which RF energy is confined into a small area (about 3 cm^2 for WG16), and applied to sensitive tissues (the lens of the eye). NEVER look down a wave guide unless you are quite sure there is no RF source at the other end!

There is a tendency to single-out microwave radiation as being especially hazardous. This is not correct, as Fig. 1 shows, though the practical situations in which high RF power densities could occur may not readily be anticipated by beginners who are unfamiliar with microwave technology. However, the level of skill required to generate large amounts of microwave power should be more than sufficient to anticipate and avoid the potential hazards.

3. Working on high power VHF/UHF amplifiers with the covers off

Quite apart from the potential RF and high voltage hazards, testing an amplifier with a cover off the anode circuit is unlikely to be useful, for the patterns of circulating RF currents may be entirely changed.

Sadly there is no substitute for the use of a large number of securing screws, or for the tedium of removing and retightening them all, each time a change is made. Note that even a narrow gap between two covers can make an effective slot radiator if it is an appreciable fraction of a wavelength long: never peer through such a gap. If access or viewing ports are essential, round holes are best; for example, a hole of about 2 cm diameter results in very little RF leakage at 144 MHz.

4. Using a small antenna in the shack as a dummy load

This is very bad practice; the use of a proper screened dummy load is essential. Quite high RF power densities can be achieved close to small antennas such as VHF/UHF dipoles if the RF power level is a few tens of watts or more.

5. Adjusting energised antennas

This is also bad practice. "Live" adjustment is very convenient, but it can and should be done at very low power levels.

6. Using handy-talkies with "rubber duck" antennas

This is not necessarily to be avoided as being unduly hazardous, but it does lead to higher RF power densities in sensitive tissue (the eye) than almost any other activity in amateur radio[3, 4] and it is of course a very common practice.

The E-field at the end of a foreshortened antenna such as the "rubber duck" (or normal-mode helix, to give it its proper name) is greater than that at the end of a full quarter-wave, and on a handy-talky the end-cap of the "rubber duck" can come quite close to the eyes and face. Extremely close contact with the end of the antenna is usually prevented by a very thick insulating end-cap on commercial antennas of this type. The authors strongly recommend amateur constructors to take similar precautions, for direct contact with the uninsulated end of a "rubber duck" could cause a corneal burn at power levels of only 1-2 W.

ENVIRONMENTAL RF FIELDS

So far in this article the authors have concentrated mainly on potential RF hazards to the station operator. In order to obtain some indication of typical RF power densities generated in the environment of amateur radio stations, they also made a limited survey of fixed stations.

STATION A. 300 W PEP RF output on 144 MHz, to a 16-element Yagi on an 11 m mast beside the house. Maximum power density near ground level occurred at 35 m from the base of the mast in the direction of the main beam, and was 0.03 mW/cm^2; at a distance of 60 m the power density had fallen to 0.0003 mW/cm^2, the detection limit of the instrument in use. No fields could be detected at the base of the mast or in the shack or the rest of the house.

STATION B. 400 W PEP RF output on 144 MHz, to a 16-element Yagi 3 m above the centre of the roof. Inside the loft, at the peak of the ridge directly below the antenna, the indicated RF power density was 0.2 mW/cm^2. Otherwise the results were very similar to those for station A.

STATION C. 400 W PEP RF output on 432 MHz, to a 20-element loop Yagi on an 11 m mast beside the house. No RF field was indicated (ie less than 0.0003 mW/cm^2)

in the shack, anywhere outside near ground level, or even when leaning out of the bedroom window.

STATION D. 400 W PEP RF output on 28 MHz to a TH6DXX multiband beam, which behaves as a four-element Yagi on 28 MHz. The beam is mounted on a crankup tower, 20 m from the house. With the beam at a height of 11 m, pointed at the house, the power density at the nearest upstairs bedroom window, 7 m below the plane of the beam, was 0.01 mW/cm^2. The greatest power density observed outside, close to ground level, was 0.06 mW/cm^{2}at the foot of the tower.

Although the above information is circumstantial, and could not be used to accurately predict RF power densities at other locations, the general conclusions are clear enough. In all cases the measured power densities were very much less than 10 mW/cm^2, even though the stations concerned were using powers up to the UK legal limit. Two of the stations had kilowatt permits for experimental work, and it is clear that the increase in power beyond the normal limit would introduce no appreciable hazard. In this survey the highest RF power densities encountered were where the height differences were small: in the loft at station B, and upstairs at station D when the tower was retracted.

In order to obtain any appreciable environmental RF power density, therefore one needs the rather unusual combination of high RF power but a low antenna. Virtually all fixed stations have antennas high enough to preclude the possibility of anyone approaching them closely; this is another example of the way that normal good practice tends to control potential RF hazards without any special precautions to that end.

One possible exception to this general rule is the ground-mounted $\lambda/4$ vertical antenna, especially on 28 MHz. A recent calculation[5] has shown that standing very close (20 cm) to a 27 MHz ground-mounted $\lambda/4$ vertical fed with 140 W of RF can lead to the same energy absorption as would standing in a 10 mW/cm^2 plane-wave field. However, the energy absorption is considerably reduced if the subject is not perfectly grounded.

MOBILE OPERATION

In mobile operation the antenna is low, but in most cases the RF power is also low. There is an effective limit of about 100 W RF output because of the drain on the battery while stationary, and in the UK the legal power limits are only a little above this level. Even when using such power levels, the operator can still control any RF hazards simply by making sure that nobody remains close to the antenna while the transmitter is in use, or by refraining from transmitting high power if anyone is close by; and of course the problem disappears when the car is in motion.

CONCLUSIONS

Heating appears to be the *only* biologically-significant property of RF energy, and is only a hazard if the heat cannot be removed quickly enough by the body's thermostatic mechanisms.

Absorption of RF energy by the human body diminishes rapidly with frequency in the HF region, and is relatively constant in the microwave region. The slightly enhanced absorption occurring near the resonant frequency of the human body is not a major cause for concern.

Normal good RF engineering practice automatically tends to control any potential hazards to the station operator. However, commonsense suggests that situations in which RF power densities *may* be high are best avoided as a matter of principle, even if they may not prove unduly hazardous in practice.

At fixed stations the normal use of high antennas tends to reduce the environmental RF power density in accessible places to very much less than the maximum levels considered acceptable.

Even if areas of relatively high RF power density are potentially accessible, the operator can still control any hazard by preventing access or by not transmitting when anybody is in such an area.

The authors see no reason whatever for treating RF hazards any differently from other hazards of amateur radio that are better known, accepted and controlled, eg high voltages or falling antennas. There is no case for introducing any special regulations, on any amateur band, aimed at controlling RF hazards due to amateur radio.

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INTERNATIONAL NEWS

NEW INTERNATIONAL FOCUS FOR 73 JOURNAL

Beginning with its April issue, *73: Amateur Radio's Technical Journal* will be offering a new column, "73 International".

Written by columnists from around the globe, "73 International" will offer its readers a broader knowledge of amateur radio activity throughout the world and provide foreign amateurs with an international outlet through which they can publicise their operations.

The April issue will include columns from India, Hong Kong, Taiwan, Korea and Papua New Guinea. Guam, New Zealand, Chile, Brazil, Switzerland, Austria, Sweden and West Germany will also be represented in that issue.

By fostering an international forum for amateurs, *73* hopes to encourage the growth of amateur radio worldwide and to cross the traditional boundaries of technological co-operation. Further information is available from Avery L Jenkins WB8JLG.

AMERICAN RADIO RELAY LEAGUE NATIONAL CONVENTION

The 1984 ARRL National Convention will be hosted by the Hudson Division at the New York Statler, on the weekend of 20-22 July. The popular event, which usually attracts amateurs from every one of the fifty United States, all Canadian provinces and many countries abroad, is scheduled to feature numerous activities including technical and operating seminars, social events, banquets, DX meetings, manufacturer's displays showing the latest equipment designs and unlimited activities for non-amateur spouses.

The New York Statler is situated in the heart of the city, which provides visiting amateurs and their families easy access to its many cultural attractions. Broadway's famous theatre district, the Empire State Building, the World Trade Centre's twin towers, the bohemian Greenwich Village artists' colony, plus opera houses, museums and numerous restaurants featuring cuisine from nearly every nation, are all within minutes of the hotel via taxi, bus or subway. The hotel itself offers every amenity of a cosmopolitan inn, including dining rooms, conference rooms, lounges and a Grand Ballroom which can accommodate up to 2000 people.

Detailed information and registration forms may be obtained by writing to Mike Troy, AJ1J, R.R. 4 — Box 19C, Pound Ridge, New York 10576, USA.

HOW DANGEROUS IS RF RADIATION?

— Part Three

In this our third and final article of possible RF radiation hazards, the matter of Microwave RF hazards is discussed. The article was first published in Radio Communication, April 1982.

We trust that all WIA members have gained a little further information from this series of articles, and we invite your comments either by letter to the editor or direct to your division. —

MICROWAVE RF HAZARDS

By D. S. Evans, PhD, BSc, FIM, G3RPE*
RSGB microwave manager
Reproduced from Radio Communication April 1982

An earlier article[1] introduced the general topic of the safety or otherwise of RF sources such as transmitters. It was pointed out that a hazard could exist if parts of the body absorbed sufficiently large amounts of RF energy to cause overheating. By the very nature of the hazard, it is impossible to specify any absolutely safe or unsafe level of RF power with any precision. However, the main conclusion of the article referred to (as well as others of a similar nature) is that with typical amateur HF and VHF stations where the antennas are mounted well above ground level, the measured RF levels at points of close access generally are at least 100-fold down and up to several orders of magnitude lower than the standard "safe" level of 10 mW/cm^2 even when using full legal power. In these practical cases, therefore, there clearly are few problems, and even arguments about what constitutes a "safe" level become somewhat academic.

However, the RF level associated with even relatively low-power transmitters can increase to an unacceptably high level as one gets close to them, and the article emphasised the care that must be taken in testing equipment on the bench with covers removed or with unscreened dummy loads. Handy-talkies, especially those using "rubber duck" antennas, may represent a hazard if their power output exceeds a few watts.

While the same basic principles regarding RF hazards apply also in the microwave area, there are significant differences compared with lower frequencies. For example, microwave equipment is more often operated near ground level for various reasons; there is more experimental development of equipment; and, for a given transmitter power, the RF power density close to the antenna will tend to increase with frequency. For these and other considerations, the topic of RF hazards at microwaves is best dealt with separately and in perhaps more detail than at HF and VHF.

Anyone involved in safety matters, whatever the area, will be well aware how difficult it is to maintain a sense of perspective. The illogicality of many safety procedures bears testimony to this. It is all too easy to "play safe" and lay down over-restrictive rules which, at best, simply inhibit activity and, at worst, become discredited and then ignored. The objective of this article is to attempt to develop a code of practice appropriate for day-by-day use by amateurs which will reduce to a minimum the risk involved to operators and bystanders. This code is summarised below. It is followed by an outline of the nature of the hazard, and the technical background employed in developing the code.

SAFE GENERATING PRACTICES WITH MICROWAVE EQUIPMENT

It is easy to demonstrate that the maximum RF power density associated with amateur microwave equipment will almost always be significantly lower than 10 mW/cm^2 at even a short distance away from the antenna. Indeed, it would be rather difficult to produce a practical system in which this level was exceeded at any distance. In any case, equipment parameters can be specified to ensure that it does not. However, where the effective aperture of a system carrying RF is small, eg the open end of waveguide and in feeds for dishes, the density can be very high and at a hazardous level. Thus for practical systems amateur microwave equipment will almost always be safe at almost any distance outside the structure of the antenna, and almost always will present a hazard within the structure, eg between the feed and a dish or inside a horn antenna. Therefore the only real risk is to operators and others who have access within a very short distance of these components.

The following is an attempt to define a code of practice for the safe handling of microwave equipment in an amateur context.

1. It must be recognised that a potential hazard exists wherever equipment having a small effective aperture — such as the open end of waveguide and coaxial cable, horn and rod feeds — carries RF above a level ranging from 1 mW at 24 GHz to a few hundred milliwatts at 1.3 GHz. As a guide, the input power should not exceed 2.5 mW/cm^2 of area of the aperture if the maximum RF power density is not to exceed 10 mW/cm^2.
2. For these small apertures, the maximum RF density is reached at a distance

typically $\lambda/10$ to 1λ from the aperture and falls rapidly by a factor of 100 at a distance of 1-10λ: the potential hazard therefore exists over a short range only.

3. When working in close proximity to equipment, it is highly desirable to reduce power levels to below those given in **1**. Where this is not possible, it is essential to dissipate the power in a screened load.
4. One golden rule should be to ensure *no* RF is present before looking down waveguide, because of the special vulnerability of the eye.
5. With high-power equipment, a hazard may exist through leakage of RF from loosely-coupled connectors and waveguide flanges, and from the coupled output of directional couplers. The power *reflected* from surfaces may exceed a safe level. Clearly, good practice demands care and discipline — and foresight.
6. It is strongly recommended that the RF power fed to a paraboloidal dish reflector should not exceed 2.5 mW of its projected area. This will ensure that the RF power density will nowhere exceed 10 mW/cm^2 except for the region between the feed and the dish. This limit corresponds to approximately 2 W for a dish 0.3 m in diameter, and 80 W for a dish 2 m in diameter, and therefore is unlikely to present any practical limitations to the design of equipment.
7. If the dish is fed using the Cassegrain system, then it is recommended that the power delivered to the antenna should not exceed 25 mW/cm^2 of the area of the *sub-reflector*, or 2.5 mW of that of the main reflector, whichever is the smaller value. In this case the leakage of RF around the sub-reflector should be less than 10 mW/cm^2.
8. Care must be taken to ensure that the feed is placed in the correct position at the focus of the dish. If further from the dish than this optimum value, an image of the feed will be produced at a finite distance. The RF power density at this point may approach that at the feed and therefore be at an unsafe level. It is clearly good practice to align antennas using powers at the milliwatt levels as given in **1**.
9. If the power to an antenna is limited as in **5** and **6**, then the RF power density will be at a safe level everywhere other than in the region between the feed and the dish. As the power density at the feed may be very high, it is essential to limit access to this region, especially by those unfamiliar with the hazard. This can be achieved either by restricting access to the site or by raising the antenna so that its height at the centre exceeds 3 m.
10. In the case of horn antennas it is recommended that the power level should be limited to 2.5 mW/cm^2 of the area of the aperture. For most horns this is equivalent to $2 \times l^2$ where l is the length of the longest side of the aperture.
11. Higher power densities can of course be tolerated provided the operator of the equipment ensures that people cannot have access to these regions.

NATURE OF THE HAZARD

As was pointed out in **1**, the hazard associated with high RF levels is completely unconnected with radiation hazards associated with γ- or X-rays for example. It is simply that of heating of parts of the body following absorption of the radiation, and therefore is similar to the hazard of over-exposure to the sun or sitting too near a fire. The effectiveness of this form of heating is well demonstrated by the microwave ovens with which amateurs share the 2.3 GHz band. The main factor affecting the degree of hazard is the power density of the RF intercepted by the body. Convenient units are either watts per square metre or milliwatts per square centimetre. A second factor is the frequency of radiation, which affects the proportion of incident radiation absorbed, the site of its absorption and the power density developed by a transmitter of a given output power. These factors will be discussed below.

The effect of controlled heating can be positively beneficial, as in diathermy treatment, but large doses or even an accumulation of doses can lead to permanent damage to body tissues without a person necessarily being aware at the time that this damage is being done. One of the more vulnerable organs is the eye: the viscous fluid within the eye is affected by heat in much the same way as the white of an egg, which is transparent at room temperature but becomes opaque when warmed. In the eye, as in the egg, the process is irreversible.

Physiological characteristics also affect the degree of hazard. Thus at lower frequencies the intestines tend to be vulnerable because this is the region in which heat is generated and, being not particularly well-endowed with nerves, the effect is not immediately felt. The eye is also vulnerable because it has no bloodstream to assist in dissipating any heat that may be generated, although the same effect will also be observed at extremities such as the fingers. The effect of frequency of the radiation is quite critical. Below about 150 MHz the human body tends to become transparent to RF radiation and therefore there is no real problem. At VHF the radiation penetrates deeply into the body, and the more vulnerable parts are the internal organs. At 1-10 GHz the energy tends to be dissipated in the skin and the organs immediately below the surface: at high power densities there is a sensation of warmth. Above 10 GHz energy is absorbed in the surface layers, although it appears that a high proportion of the incident RF will be reflected.

There is a further effect which relates the absorption with the size of the organ and the wavelength of radiation. Radiation of a given density having a wavelength of 23 cm, for example, will have less effect on the eyes which have dimensions of one or two centimetres than radiation of wavelength of 3 cm, ie 10 GHz.

Another potential influence of frequency is that of affecting the RF power densities likely to be produced in practice. For a transmitter of given power, the radiation density developed is roughly proportional to frequency. However, the amount of power that can be generated tends to fall by a corresponding amount, and thereby balancing the risk of a hazard.

Frequency is also important in the way it influences the design and use of the equipment. At lower frequencies, antennas have relatively low gain and coaxial cables have low loss: this means that antennas can readily be mounted high, usually tens of feet above ground level. At high microwave frequencies, however, there is a tendency to operate equipment near ground level. This is because antennas are so directive as to need some optical method for alignment, and cable losses so high that the antennas need to be mounted on the transmitters. These factors conspire to favour the antenna being mounted at head height, which is the least desirable from a safety point of view. Despite the complexity of the overall situation, nevertheless the majority of problems can be covered simply by specifying a maximum power level to which parts of the body should be exposed, and this is described in the following sections.

SPECIFICATION OF "SAFE" RF POWER DENSITIES

The previous section describes several of the factors affecting the degree of hazard. It is therefore not surprising that while all authorities agree that exposure to radiation having a density of more than 100 mW/cm^2 is likely to be hazardous unless special clothing is worn, there is room for discussion on what constitutes a "safe" level. The Home Office and the Medical Research Council recommend a maximum density *for continuous exposure* of 10 mW/cm^2. This figure implies some extra margin of safety in an amateur context, since exposure is unlikely to be classifiable as "continuous" or cover other than a small part of the body at one time. It is to be noted that some standards have allowed a maximum of 100 mW/cm^2 for periods up to 6 min. of exposure.

On the other hand, it is to be recognised that much amateur equipment can be of an experimental nature and not necessarily fully instrumented. Unexpectedly high radiation densities due to a power amplifier starting to oscillate, or to poor design of antennas, suggest a need for added caution. It would therefore seem wise initially to adopt a temporary arbitrary lower maximum power density during initial experimentation — possibly 1 mW/cm^2 — until the equipment is properly set up.

Frequency (GHz)	Waveguide No.	Internal dimensions (cm)	Maximum power (mW)
1.3	6	16.510 by 8.255	340
2.3	8	10.922 by 5.461	150
2.3	9A	8.636 by 4.318	93
3.4	10	7.216 by 3.403	61
5.7	12	4.755 by 2.215	26
5.7	14	3.485 by 1.580	14
10	16	2.286 by 1.016	5.8
24	20	1.067 by 0.432	1.2

Table 1. Maximum power for 10 mW/cm^2 not to be exceeded at open end of waveguide

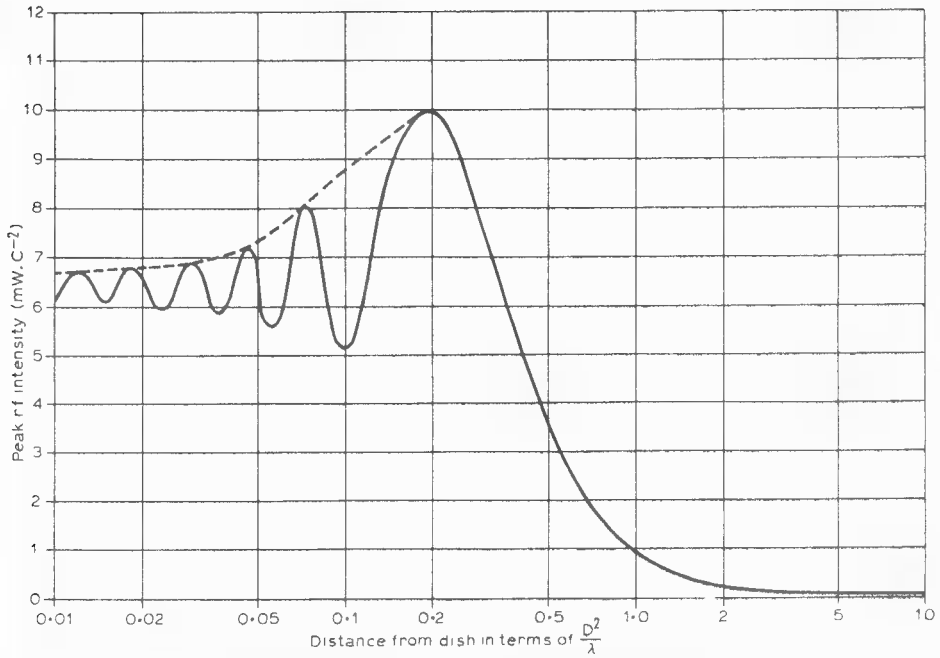

Fig. 1. Peak RF density relative to 10 mW/cm² as a function of distance from dish expressed in terms of D^2/λ, where D is the diameter of the dish and λ the wavelength of radiation, both expressed in the same units.

CHARACTERISTICS OF THE RADIATION PATTERN

It is useful to consider first radiators such as the open end of waveguides or the horn antenna, and then to move on to paraboloidal dish antennas. It can be shown that the pattern of radiation across the aperture is not uniform across a waveguide or horn in the H-plane, but follows a sine wave. Thus while the mean power across the aperture is simply P/A, where P is the power and A the area of the aperture, the peak power density is nearly four times this value, ie approximately 4P/A. The use of the latter value introduces a small safety factor which is increased by the use of the physical aperture for A rather than the electrical aperture.

The maximum power density is observed along the axis of the radiator, and falls to either side. In the case of paraboloidal dish antennas, a similar pattern is observed; the feed being designed so as to reduce the power density at the edge of the dish by typically 10 dB. The maximum density is not, as perhaps would be imagined, at the aperture, but at a distance further from the dish given by 0.2 D^2/λ, where D is the diameter of the reflector in the same units as λ. This relationship is equivalent to approximately $A/4\lambda$, which value can be used as a convenient guide with other shapes of aperture.

Between the radiator and the point of maximum power density, the density varies in a sinusoidal manner at a level of a few decibels lower than the peak value. Beyond the peak the density falls rapidly and reaches a value 20 dB down at a distance given by 2 D^2/λ (or 2.5 A/λ), and thereafter falls at a rate set by the inverse square law. The overall pattern of power density normalised in terms of D^2/λ is shown in Fig. 1 with reference to a peak density of 10 mW/cm².

OPEN ENDED WAVEGUIDE

As will become apparent, the radiation from the open end of waveguide represents probably the greatest risk in practice. It is compounded by the almost irresistable urge many people have to look into it.

The size of waveguide used at a particular frequency is set within fairly narrow limits: the broad width usually lies between 0.6 and 0.95λ, and the height usually is approximately 0.45λ. The value of A therefore is typically $0.27\lambda^2$—$0.43\lambda^2$. The maximum power P that can be fed to the waveguide without exceeding 10 mW/cm² peak RF power density is therefore $0.67\lambda^2$—$1.07\lambda^2$, where P is in milliwatts and λ in centimetres. The maximum density is measured at a distance of 0.13λ — 0.21λ in front of the aperture, and drops by a factor of 100 at a distance of 1.35λ—2.15λ. The maximum powers that should be applied to typical waveguides at frequencies of amateur interest so as not to exceed 10 mW/cm² are given in Table 1: they are seen to be at relatively low levels. This implies that in most cases the output of most transmitters constitutes a real hazard and therefore the waveguide should always be safely terminated in a screened load where access is permitted.

As an example, the maximum radiation density from a 100 mW 10 GHz transmitter based on WG16 reaches a peak value of 170 mW/cm² at a distance of approximately 5 mm in front of the waveguide aperture. However, this falls to 1.7 mW/cm² at a distance of approximately 40 mm from the waveguide aperture.

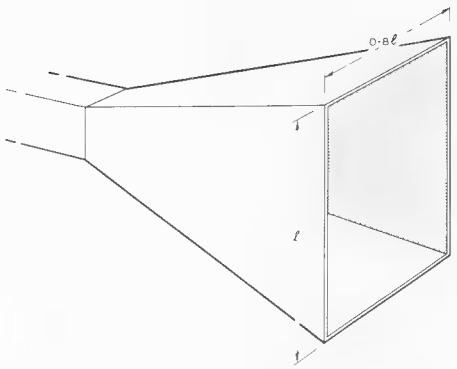

Fig. 2. Typical horn antenna.

HORN ANTENNAS

In the form generally used by amateurs, Fig. 2, horn antennas consist of a length of waveguide which is flared in both directions to produce an aperture having an aspect ratio of typically 0.8:1. The radiation density within the horn falls from a relatively high value at the throat of the horn to a low value at the aperture. For the peak radiation density anywhere *outside* the antenna not to exceed 10 mW/cm², the power in milliwatts fed to the antenna should not exceed $2 \times l^2$ where l is the length of the longer side in centimetres. Because of their relatively large physical size relative to their gain, horn antennas tend to be used at frequencies of 10 GHz and above. At that frequency a reasonably large horn would have an aperture of 30 by 24 cm. The maximum power that could be fed to this antenna without exceeding 10 mW/cm² at the aperture would be 1.8 W, a very considerable power at that frequency.

The power density at the aperture is given by $5P/l^2$. For a medium size (10 GHz) transmitter of output power 100 mW, the density is only 0.6 mW/cm², ie at a very safe level. The corresponding density at the throat increases to 170 mW/cm², but this region is not easily accessible other than by deliberate action. For this reason, and the fact that they cannot be misaligned, horns tend to be a particularly safe form of antenna to use.

A feature of note is that the aperture of the horn is increased so the gain of the antenna increases, and therefore the effective radiated power is raised. At the same time, the larger the aperture the lower the power density at the aperture, and therefore the safer the equipment becomes. We therefore have the perhaps surprising situation that, for a given transmitter output, it is possible to have the situation that the higher the radiated power the safer the equipment can become.

PARABOLOIDAL DISH ANTENNAS

This is the most popular form of microwave antenna. It consists of a paraboloidal reflector to which RF is fed by some form of feed placed at its focus. There are two areas of importance, which can be dealt with separately: the hazard associated with the radiation reflected by the dish and which will be at a maximum at some distance outside its focus; and the hazard associated with the region between the feed and the dish.

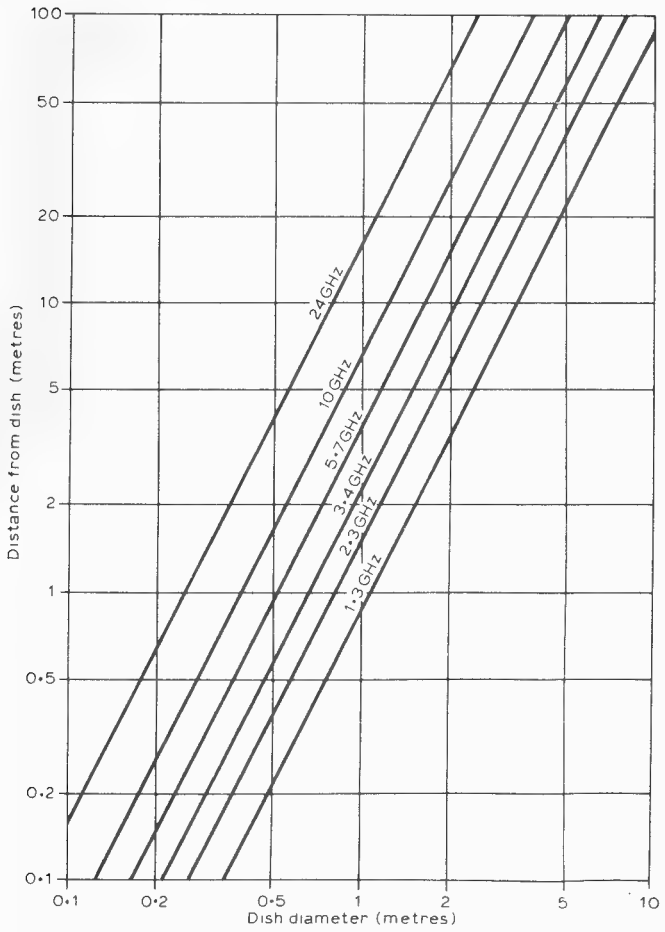

Fig. 3. Distance from dish to point of maximum RF density as a function of frequency and dish size.

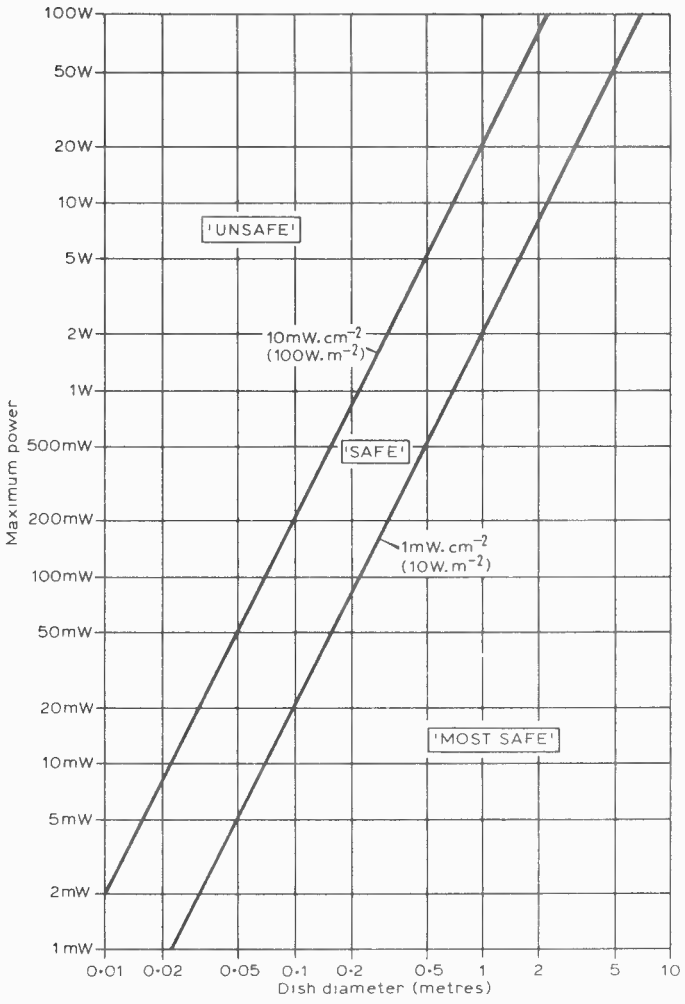

Fig. 4. Maximum power to be fed to a dish so as not to exceed an RF density of 1 or 10 mW/cm².

REFLECTED POWER

The pattern of radiation from a dish reflector is approximately a cone. This has an initial diameter equal to that of the dish, which increases with distance from the dish according to the beamwidth of the antenna. The radiation density across this cone is at a maximum at its centre, ie along the axis of the dish, and is designed to fall typically by about 10 dB at the edge of the cone. Along the axis the peak radiation density is found near the limit of the near field, ie at a distance $0.2\ D^2/\lambda$ from the dish, where D and λ respectively are the diameter of the dish and the wavelength of the RF expressed in the same units. Values for frequencies of amateur interest as a function of antenna size are shown in Fig 3.

The peak radiation density in most cases will be observed at distances of 1 to 10 m from the dish, ie well beyond the focus. The peak radiation density corresponding to this reflected power is again given by the value 4P/A, where P is input power in milliwatts and A is the projected area of the dish in square centimetres. For this peak density not to exceed 10 mW/cm², the maximum power should not exceed the values:

$P_{max} = 2\ D^2$ where P is in milliwatts, D (diameter) in centimetres

$P_{max} = 20\ D^2$ where P is in watts and D in metres.

This relationship, together with that for a maximum density of 1 mW/cm², is shown as a function of dish diameter in Fig 4, with regions designated as "most safe", "safe" and "unsafe". Thus, for example, if a 1.5 m dish is available, provided that the power fed to it does not exceed 44 W, then nowhere outside the antenna structure will the power density be greater than 10 mW/cm². It should be noted that this relationship is independent of frequency. This means in practice that a high degree of safe operaton can be "built-in" a system by simply specifying its parameters. The above data of course presumes that the dish and feed are properly aligned: the effects of misalignment is discussed below. As was the case with horn antennas, for a given transmitter power, the larger the size of the dish the safer the equipment becomes, despite the fact that the effective radiated power is increased.

THE HAZARD ASSOCIATED WITH THE FEED

It was shown in the previous section that provided the power supplied to a parabolic reflector was related in the way described to its diameter, then the radiation density could be held to a safe level anywhere outside the antenna. This could be achieved in practice without placing too restrictive limitations on the equipment design. For example, Fig 4 shows that the minimum size of dish to be used with a 2 W transmitter should be 1 m diameter if the radiation density external to the antenna structure is not to exceed 1 mW/cm², or 20 W if not to exceed 10 mW/cm².

However, as the effective aperture of the feed supplying this power to the dish is usually much smaller than that of the dish, the radiation density associated with the feed will usually be at an unsafe level, and frequently at a hazardous level. The situation is somewhat similar to the horn antenna described earlier except that with a horn it is relatively difficult to physically reach the regions of high radiation density, whereas with a dish it is normally all too easy if the antenna is near ground level or not otherwise protected. The actual power density between the feed and the reflector will be set by the power of the transmitter and the dimensions of the feed. One of the simplest cases is that of the direct horn

feed, in which the horn is mounted at the focus of the dish with its aperture directed at the dish. The actual dimensions of the feed depend on the frequency of operation and the ratio of the focal length of the paraboloidal reflector to its diameter, in the manner described in **2**. If it is assumed that access to the inside of the horn feed is prevented, then the maximum power that can be applied to the feed so as not to exceed a radiation density of 10 mW/cm² as a function of the focal length/diameter (f/D) ratio of the dish and of frequency. These levels should be adopted if the system is to be operated at ground level for alignment.

Practical transmitters will normally generate significantly greater powers than those shown in Table 2. For a 1 W transmitter at 10 GHz, for example, the peak radiation density in front of a feed will be in the range of a few hundred milliwatts to a few watts per square centimetre depending on the f/D ratio of the dish. These levels are clearly unsafe, and it therefore makes good sense to operate the antenna in such a way as ensures that the operator and others cannot have access to that region of the antenna.

A popular second type of feed is the Cassegrain system, in which a horn feed mounted through the centre of the dish radiates a sub-reflector which in turn illuminates the main reflector. With this system the main risk would seem to be spillage of RF around the edges of the sub-reflector. If this is to be limited to 10 mW/cm², and the feed has a normal taper, in illumination of 10 dB, then the radiation density at the centre of the sub-reflector must not exceed 100 mW/cm². This is achieved if the power supplied to the antenna does not exceed 25 AmW, where A is the area of the *sub-reflector* in square centimetres.

Calculations of radiation density around dipole-reflector combinations are difficult. There seems little doubt that stray radiation is likely to be at a somewhat higher level than with horn feeds, and therefore correspondingly greater precautions should be taken with this type of feed.

Frequency (GHz)	Maximum power (mW) f/D = 0.25	f/D = 0.6	f/D = 1.0
1.3	370	1400	4500
2.3	120	440	1400
3.4	60	200	660
5.7	25	70	230
10	6	20	70
24	1	4	13

Table 2. Maximum power to be fed to a pyramidal horn feed as a function of f/D ratio for peak density not to exceed 10 mW/cm²

THE EFFECT OF DEFICIENCIES IN THE ANTENNA SYSTEM

It is appropriate to refer briefly to a number of deficiencies in antenna systems which in some cases may lead to unexpected problems.

(a) Under-illumination of dish
In defining the maximum radiation density by the relationship 4P/A, the area A corresponds to the physical area of the reflector *assuming ideal illumination*. The use of a feed of too high a gain will result in under-illumination of the reflector so that its effective area is smaller than the physical area. This will lead to a higher power density close to the dish than would otherwise be expected.

(b) Over-illumination of dish
If the gain of the feed is too low, then an excessive amount of energy will spill over the edge of the dish. This will not be hazardous unless the power fed to the dish greatly exceeds the recommended value, as the density is normally designed to fall by typically 10 dB between the centre and edge of the dish.

(c) Feed positioned inside the focus
If the feed is placed between the focus and the dish, the reflected beam will be divergent. As this will reduce the power density, this condition is relatively safe.

(d) Feed positioned beyond the focus
This is a potentially dangerous case because the reflected beam will tend to converge to a point some distance in front of the dish, with the risk that local power densities will approach those at the feed.

ROD ARRAY ANTENNAS

This case deserves to be considered as a separate situation. In general terms the stray radiation from this form of antenna would be expected to be greater than either horn antennas, or horn-fed dishes, and therefore greater precautions should be taken. It seems probable that the radiation pattern at a distance will be similar to that of a parabolic antenna of similar gain, and therefore the present design information will be relevant.

OTHER PRECAUTIONS

With high-power equipment it should be recognised that there are a number of other sources of hazards. For example, the leakage of RF from loosely-coupled connectors and waveguide flanges or the coupled output from a directional coupler may be at a sufficiently high level to represent a risk. In some cases, the power *reflected* from some surfaces may be at an unsafe level. It is obviously wise to recognise these possibilities and to adopt the same high standards of discipline for RF as amateurs obviously already do with other hazards such as high voltages.

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2. *VHF/UHF Manual*, D. S. Evans, G3RPE, and G. R. Jessop, G6JP. RSGB.

The Repeater Group L to R: seated — VK2DHR, VK2DDD, VK2APP, (chairman) VK2DBI, XYL of VK2APP. Standing — VK2ENH, VK2BQW, VK2DWT, VK2XAQ, VK2PAM, VK2DHO and VK2AMV. (Missing from group is VK2EEE). In the foreground of the photo are the cavity filters on the table at the left, the repeater right and solar cells standing against table.

Photograph by John Meagher VK2AMV.

CLUB CORNER

John Meagher VK2AMV
87 Rankin Street, Forbes, NSW, 2871

REPEATER GROUP

A group of amateurs from the "Weddin Repeater Group" are working towards establishing a repeater in the Grenfell area of Central New South Wales.

The proposed repeater will serve from Dubbo to Cootamundra, Young, Temora, Wyalong and hopefully Griffith, Parkes, Condobolin and Forbes. Tests already carried out from the proposed site have been most encouraging.

The repeater is to operate on channel 10-147.100 MHz and is presently under test in a temporary location at Forbes.

AR